TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Hatchie River Watershed (HUC 08010208)

Chester, Fayette, Hardeman, Haywood, Lauderdale, Madison, and Tipton Counties, Tennessee

FINAL

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March 5, 2008

TABLE OF CONTENTS

1.0 INTRODUCTION………………………………………………………………………… 1

2.0 SCOPE OF DOCUMENT………………………………………………………………. 1

3.0 WATERSHED DESCRIPTION………………………………………………………… 1

4.0 PROBLEM DEFINITION……………………………………………………………….. 4

5.0 WATER QUALITY CRITERIA & TMDL TARGET…………………………………………. 8

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET………………….. 8

7.0 SOURCE ASSESSMENT……………………………………………………………… 11

- 7.1 Point Sources……………………………………………………………………… 11
- 7.2 Nonpoint Sources…………………………………………………………………. 13

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD……………………………… 17

- 8.1 Expression of TMDLs, WLAs, and LAs……………………………………… 17
- 8.2 Area Basis for TMDL Analysis ……………………………………………….. 17
- 8.3 TMDL Analysis Methodology…………………………………………………… 17
- 8.4 Critical Conditions and Seasonal Variation ………………………………… 18
- 8.5 Margin of Safety……………………………………………………………………… 18
- 8.6 Determination of TMDLs………………………………………………………… 19
- 8.7 Determination of WLAs & LAs ……………………………………………… 19

9.0 IMPLEMENTATION PLAN…………………………………………………………. 21

- 9.1 Application of Load Duration Curves for Implementation Planning …………….. 21
- 9.2 Point Sources …………………………………………………………………… 23
- 9.3 Nonpoint Sources ……………………………………………………………… 24
- 9.4 Additional Monitoring…………………………………………………………….. 28
- 9.5 Source Area Implementation Strategy …………………………………………….. 29
- 9.6 Evaluation of TMDL Implementation Effectiveness ……………………………… 35

10.0 PUBLIC PARTICIPATION………………………………………………………… 38

11.0 FURTHER INFORMATION………………………………………………………… 38

REFERENCES……………………………………………………………………………… 39

APPENDICES

Appendix		Page
A	Land Use Distribution in the Hatchie River Watershed	A-1
B	Water Quality Monitoring Data	B-1
C	Load Duration Curve Development and Determination of Daily Loading	C-1
D	Hydrodynamic Modeling Methodology	D-1
E	Source Area Implementation Strategy	E-1
F	Public Notice of Proposed Total Maximum Daily Loads (TMDLs) for E. coli In the Hatchie River Watershed (HUC 08010208)	F-1

LIST OF FIGURES

Figure		Page
1	Location of the Hatchie River Watershed and HUC-12 Subwatersheds	2
2	Level IV Ecoregions in the Hatchie River Watershed	3
3	Land Use Characteristics of the Hatchie River Watershed	5
4	Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List)	7
5	Monitoring Stations and CAFOs located in the Hatchie River Watershed	10
6	Land Use Area of Hatchie River Watershed Drainage Areas Flat Creek, Richland Creek, and Catron Creek	15
7	Land Use Percent of Hatchie River Watershed Drainage Areas Flat Creek, Richland Creek, and Catron Creek	15
8	Land Use Area of Hatchie River HUC-12 Subwatershed 0701 and Drainage Area Cane Creek Waterbody TN08010208034-2000	16
9	Land Use Percent of Hatchie River HUC-12 Subwatershed 0701 and Drainage Area Cane Creek Waterbody TN08010208034-2000	16
10	Five-Zone Flow Duration Curve for Cane Creek at RM 12.5	22
11	Tennessee Department of Agriculture Best Management Practices located in the Hatchie River Watershed Load Duration Curve for Implementation Planning	27
12	Oostanaula Creek TMDL implementation effectiveness (box and whisker plot)	36
13	Oostanaula Creek TMDL implementation effectiveness (LDC analysis)	36
14	Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis)	37
C-1	Flow Duration Curve for Richland Creek at Mile 1.8	C-6
C-2	E. Coli Load Duration Curve for Richland Creek at Mile 1.8	C-6
D-1	Hydrologic Calibration: Cane Creek at Ripley (USGS 07029500)	D-4
E-1	Flow Duration Curve for Hyde Creek	E-3
E-2	E. Coli Load Duration Curve for Hyde Creek at Mile 1.6	E-3
E-3	Flow Duration Curve for Catron Creek	E-6
E-4	E. Coli Load Duration Curve for Catron Creek at Mile 3.1	E-6
E-5	Flow Duration Curve for Flat Creek	E-10
E-6	Flow Duration Curve for Richland Creek	E-10
E-7	Flow Duration Curve for Old Cnannel Nelson Creek	E-11
E-8	Flow Duration Curve for Cane Creek (HUC-12: 0701)	E-11
E-9	Flow Duration Curve for Cane Creek, waterbody TN08010208034-3000	E-12
E-10	Flow Duration Curve for Cane Creek, waterbody TN08010208034-2000	E-12
E-11	E. Coli Load Duration Curve for Flat Creek at Mile 1.8	E-13

LIST OF FIGURES (Cont.)

Figure		Page
E-12	E. Coli Load Duration Curve for Richland Creek at Mile 1.8	E-13
E-13	E. Coli Load Duration Curve for Old Channel Nelson Creek at Mile 0.6	E-14
E-14	E. Coli Load Duration Curve for Cane Creek at Mile 15.5	E-14
E-15	E. Coli Load Duration Curve for Cane Creek at Mile 12.5	E-15

LIST OF TABLES

Table		Page
1	MRLC Land Use Distribution – Hatchie River Watershed	4
2	Final 2006 303(d) List for E. coli – Hatchie River Watershed	6
3	Summary of Water Quality Monitoring Data	9
4	Livestock Distribution in the Hatchie River Watershed	14
5	Population on Septic Systems in the Hatchie River Watershed	14
6	Determination of Analysis Areas for TMDL Development	18
7	WLAs & LAs for Hatchie River, Tennessee	20
8	Source area types for waterbody drainage area analysis	30
9	Example Urban Area Management Practice/Hydrologic Flow Zone Considerations	32
10	Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations	33
A-1	MRLC Land Use Distribution of Hatchie River Subwatersheds	A-2
B-1	Water Quality Monitoring Data – Hatchie River Watershed	B-2
C-1	TMDLs, WLAs, & LAs for Hatchie River Watershed	C-7
D-1	Hydrologic Calibration Summary: Cane Creek at Ripley (USGS 07030100)	D-3
E-1	Load Duration Curve Summary for Urban Source Area Implementation Strategies (Example: Hyde Creek Subwatershed, HUC-12 080102080701) (4 Flow Zones)	E-5
E-2	Load Duration Curve Summary for Agricultural Source Area Implementation Strategies (Example: Catron Creek Subwatershed, HUC-12 080102080501) (4 Flow Zones)	E-7
E-3	Summary of Critical Conditions for impaired waterbodies in the Hatchie River watershed	E-9
E-4	Summary of TMDLs, MOS, WLAs, & LAs expressed as daily loads for impaired Impaired waterbodies in the Hatchie River watershed (HUC 08010208)	E-16

LIST OF ABBREVIATIONS

AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DA	Drainage Area
DEM	Digital Elevation Model
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
UTK	University of Tennessee, Knoxville
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. Coli in Selected Waterbodies of the Hatchie River Watershed (HUC 08010208)

Impaired Waterbody Information

State: Tennessee
Counties: Fayette, Haywood, Lauderdale, and Tipton
Watershed: Hatchie River (HUC 08010208)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document (from the Final 2006 303(d) List):

Waterbody ID	Waterbody	RM not Fully Supporting
TN08010208007 – 0200	CATRON CREEK	17.2
TN08010208034 – 0100	OLD CHANNEL OF NELSON CREEK	2.0
TN08010208034 – 0300	HYDE CREEK	5.7
TN08010208034 – 2000	CANE CREEK	4.5
TN08010208034 – 3000	CANE CREEK	1.0
TN08010208056 – 1000	FLAT CREEK	8.1
TN08010208073 – 1000	RICHLAND CREEK	11.0

Designated Uses:

The designated use classifications for all impaired waterbodies in the Hatchie River watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Goal:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 ml, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 ml shall be considered as having a concentration of 1 per 100 ml.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 ml. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 ml.

Note: At the time of this TMDL analysis, high quality waters were designated as Tier II and Tier III streams. The proposed revised water quality standards redefine high quality waters as Exceptional Tennessee Waters. For further information on Tennessee's current general water quality standards, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

For further information on the proposed revised general water quality standards and Tennessee's Antidegradation Statement, including the definition of Exceptional Tennessee Waters, see:

http://state.tn.us/environment/wpc/publications/1200_04_03_2nd_draft.pdf.

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli. TMDLs were developed for impaired waterbodies on HUC-12 subwatershed or waterbody drainage area basis.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Hatchie River watershed were developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Tier II or III waterbodies and 941 CFU/100 mL maximum water quality criterion for all other waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads. Load duration curves were also used to determine percent load reduction goals to meet the target maximum loading for E. coli. When sufficient data were available, load reductions were also determined based on the geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to ten years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

For each impaired waterbody, critical conditions were determined by evaluating the percent load reduction goals, for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal of the greatest magnitude corresponds with the critical flow zone.

Seasonal Variation:

The 10-year period used for LSPC model simulation and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

TMDLs, WLAs, & LAs

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (08010208__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs[a]	Leaking Collection Systems	CAFOs	MS4s[b]	
			[CFU/day]	[CFU/day]	[CFU /day]	[CFU /day]	[CFU /day]	[CFU/day/ac]	[CFU/day/ac]
0501	Catron Creek	TN08010208007 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	0	NA	$3.12 \times 10^{6} * Q$
0601	Flat Creek	TN08010208056 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	NA	$2.23 \times 10^{6} * Q$
	Richland Creek	TN08010208073 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	NA	$1.88 \times 10^{6} * Q$
0701	Old Channel of Nelson Creek	TN08010208034 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$9.18 \times 10^{7} * Q$
	Hyde Creek	TN08010208034 – 0300	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$3.10 \times 10^{6} * Q$
	Cane Creek	TN08010208034 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$7.19 \times 10^{5} * Q$
	Cane Creek	TN08010208034 – 3000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$1.12 \times 10^{6} * Q$
0702	Cane Creek	TN08010208034 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$6.27 \times 10^{5} * Q$

Note: *NA = Not applicable.*
Q = Mean Daily In-stream Flow (cfs).

a. *There are currently no WWTFs permitted to discharge E. coli in impaired subwatersheds of the Hatchie River watershed. WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards as specified in their NPDES permits.*

b. *There are currently no MS4s in impaired subwatersheds of the Hatchie River watershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.*

E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL) HATCHIE RIVER WATERSHED (HUC 08010208)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Hatchie River Watershed identified on the Final 2006 303(d) List as not supporting designated uses due to Escherichia coli (E. coli). The Hatchie River Watershed lies almost entirely in the state of Tennessee with a small portion lying in Mississippi. TMDL analyses were performed on a 12-digit hydrologic unit area (HUC-12) subwatershed or waterbody drainage area basis.

3.0 WATERSHED DESCRIPTION

The Hatchie River watershed (HUC 08010208) is located primarily in western Tennessee (Figure 1), with a small portion in northern Mississippi, and lies within the Level III Southeastern Plains (65), Mississippi Alluvial Plain (73), and Mississippi Valley Loess Plains (74) ecoregions as shown in Figure 2 (USEPA, 1997). The impaired subwatersheds lie in the Level IV Bluff Hills (74a) and Loess Plains (74b) ecoregions. For detailed information about the Hatchie River watershed, including descriptions of Level IV ecoregions, see:

http://state.tn.us/environment/wpc/watershed/wsmplans/hatchie/

The Hatchie River watershed, located in Chester, Fayette, Hardeman, Haywood, Lauderdale, Madison, and Tipton Counties, Tennessee, and Benton and Tippah Counties, Mississippi, has a drainage area of approximately 1461.6 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Hatchie River watershed have occurred since 1993 as a result of development, this is the most current land use data readily available for GIS-interfaced hydrologic model input. Land use for the Hatchie River watershed is summarized in Table 1 and shown in Figure 3. Predominate land use in the Hatchie River watershed is agriculture (49.4%) followed closely by forest (48.4%). Urban areas represent approximately 1.0% of the total drainage area of the watershed. Details of land use distribution of E. coli-impaired subwatersheds in the Hatchie River watershed are presented in Appendix A.

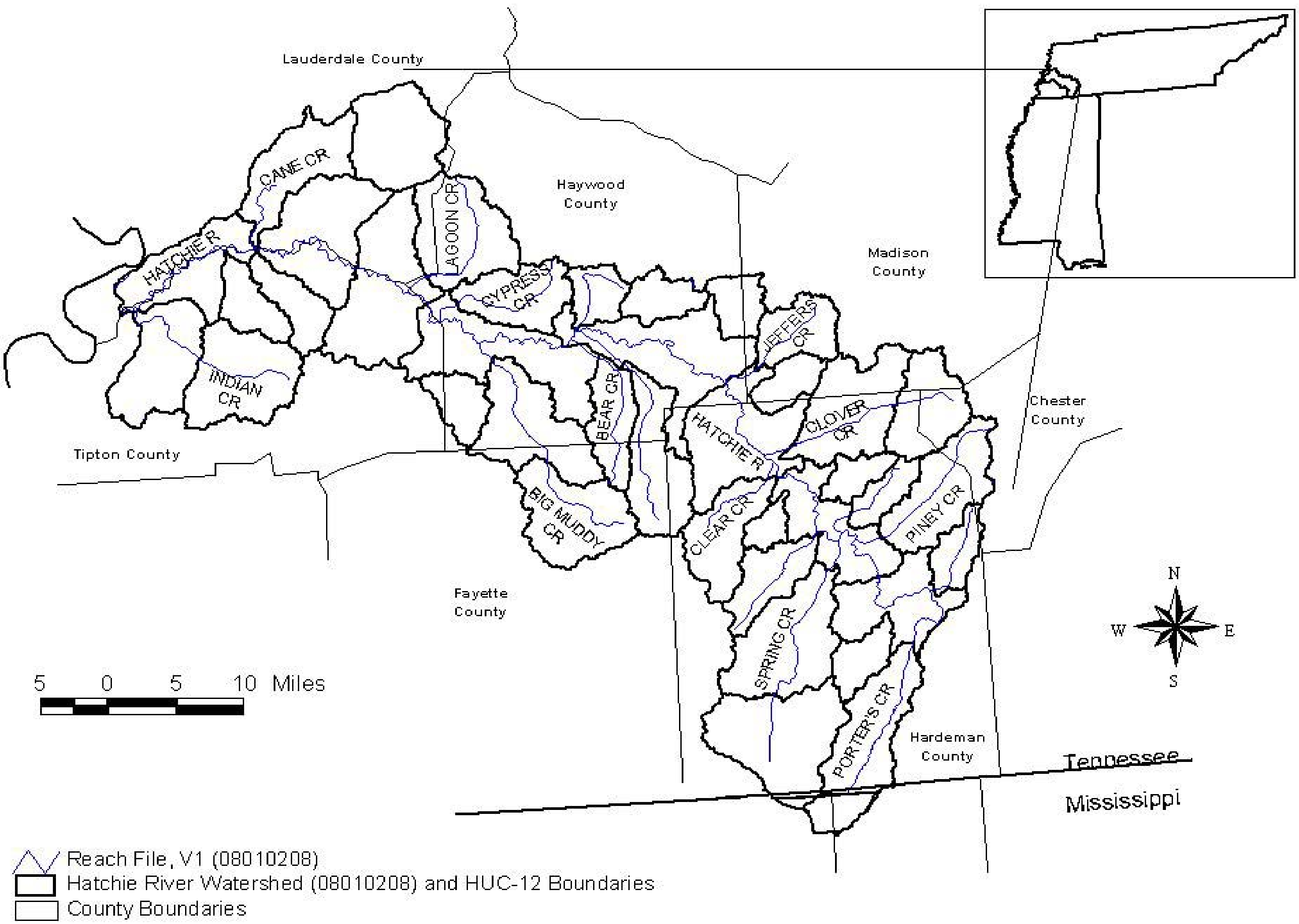

Figure 1. Location of the Hatchie River Watershed and HUC-12 Subwatersheds.

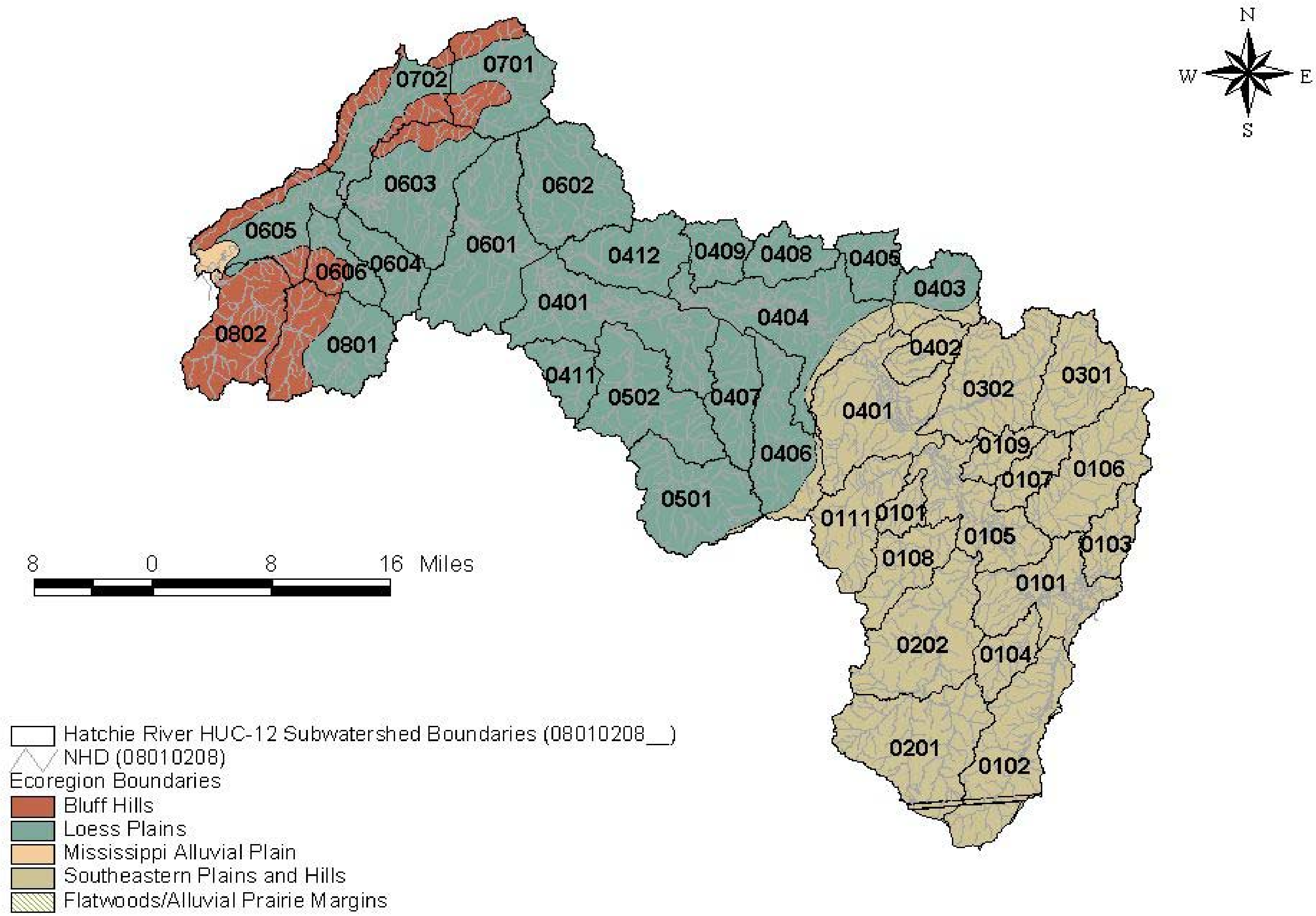

Figure 2. Level IV Ecoregions in the Hatchie River Watershed.

Table 1. MRLC Land Use Distribution – Hatchie River Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	154	0.0*
Deciduous Forest	244,293	26.1
Evergreen Forest	29,738	3.2
High Intensity Commercial/ Industrial/Transportation	1,898	0.2
High Intensity Residential	1,795	0.2
Low Intensity Residential	5,598	0.6
Mixed Forest	66,519	7.1
Open Water	8,794	0.9
Other Grasses (Urban/recreational)	901	0.1
Pasture/Hay	170,173	18.2
Quarries/Strip Mines/Gravel Pits	11	0.0*
Row Crops	291,073	31.1
Small Grains	473	0.1
Transitional	1702	0.2
Woody Wetlands	112,218	12.0
Emergent Herbaceous Wetlands	102	0.0*
Total	**935,442**	**100.00**

* < 0.05%

4.0 PROBLEM DEFINITION

The State of Tennessee's Final 2006 303(d) List (TDEC, 2006), http://state.tn.us/environment/wpc/publications/303d2006.pdf, was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. The list identified seven (7) waterbody segments in the Hatchie River watershed as not fully supporting designated use classifications due, in part, to E. coli. See Table 2 and Figure 4. The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

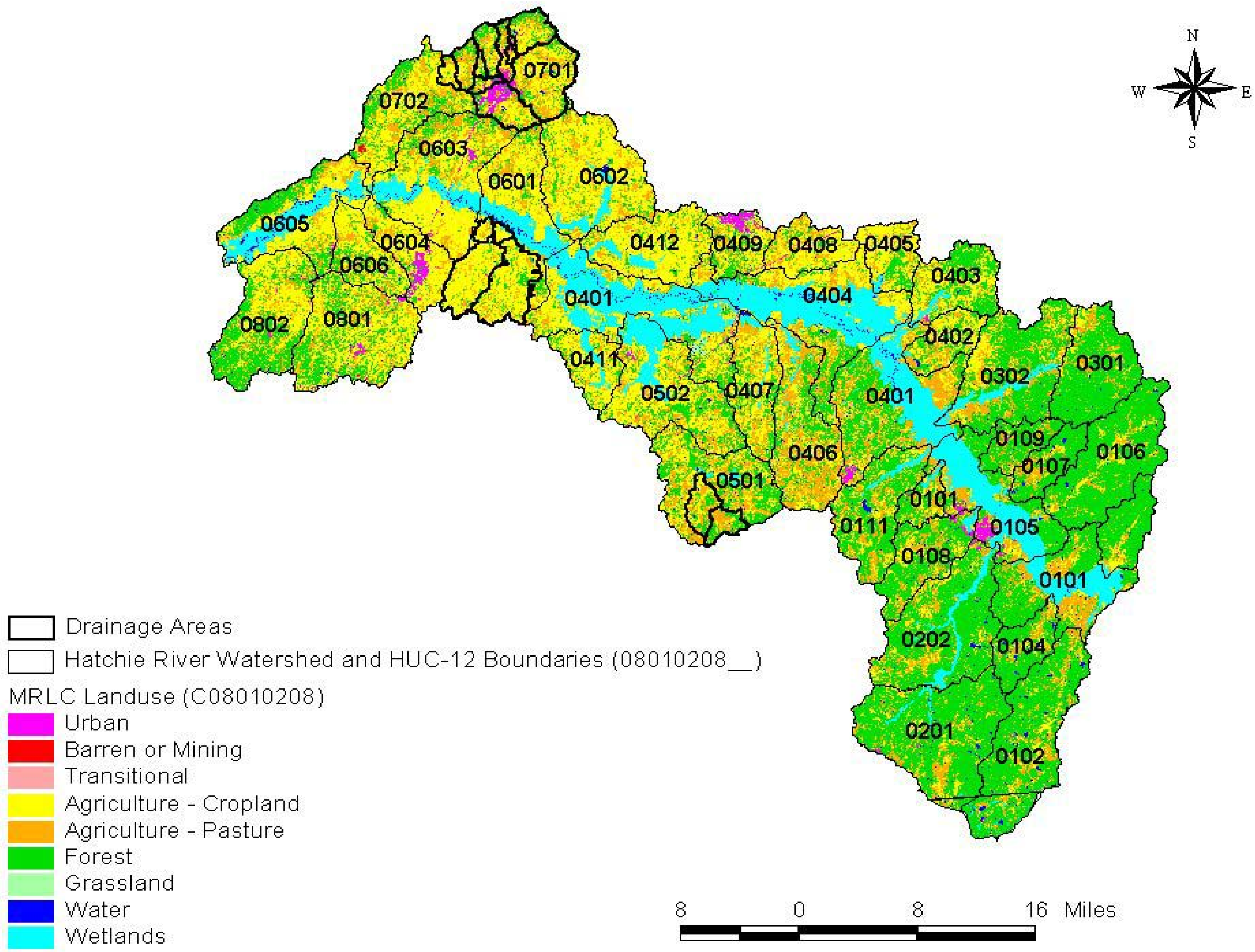

Figure 3. Land Use Characteristics of the Hatchie River Watershed.

Table 2. Final 2006 303(d) List for E. coli – Hatchie River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	CAUSE / TMDL Priority	Pollutant Source
TN080102080007 – 0200	CATRON CREEK	17.2	Escherichia coli	Pasture Grazing Permitted Confined Animal Feeding Operation
TN08010208034 – 0100	OLD CHANNEL OF NELSON CREEK	2.0	Copper Nutrients Escherichia coli	Major Industrial Point Source Undetermined Fecal Source
TN08010208034 – 0300	HYDE CREEK	5.7	Nitrate Escherichia coli	Major Industrial Point Source Collection System Failure
TN08010208034 – 2000	CANE CREEK	4.5	Copper Nitrate Physical Substrate Habitat Alterations Escherichia coli	Major Industrial Point Source Collection System Failure Channelization
TN08010208034 – 3000	CANE CREEK	1.0	Nitrate Physical Substrate Habitat Alterations Escherichia coli	Major Industrial Point Source Collection System Failure Channelization
TN08010208056 – 1000	FLAT CREEK	8.1	Nutrients Loss of biological integrity due to Siltation Physical Substrate Habitat Alterations Escherichia coli	Agriculture Channelization
TN08010208073 – 1000	RICHLAND CREEK	11.0	Nutrients Loss of biological integrity due to Siltation Physical Substrate Habitat Alterations Escherichia coli	Agriculture Channelization

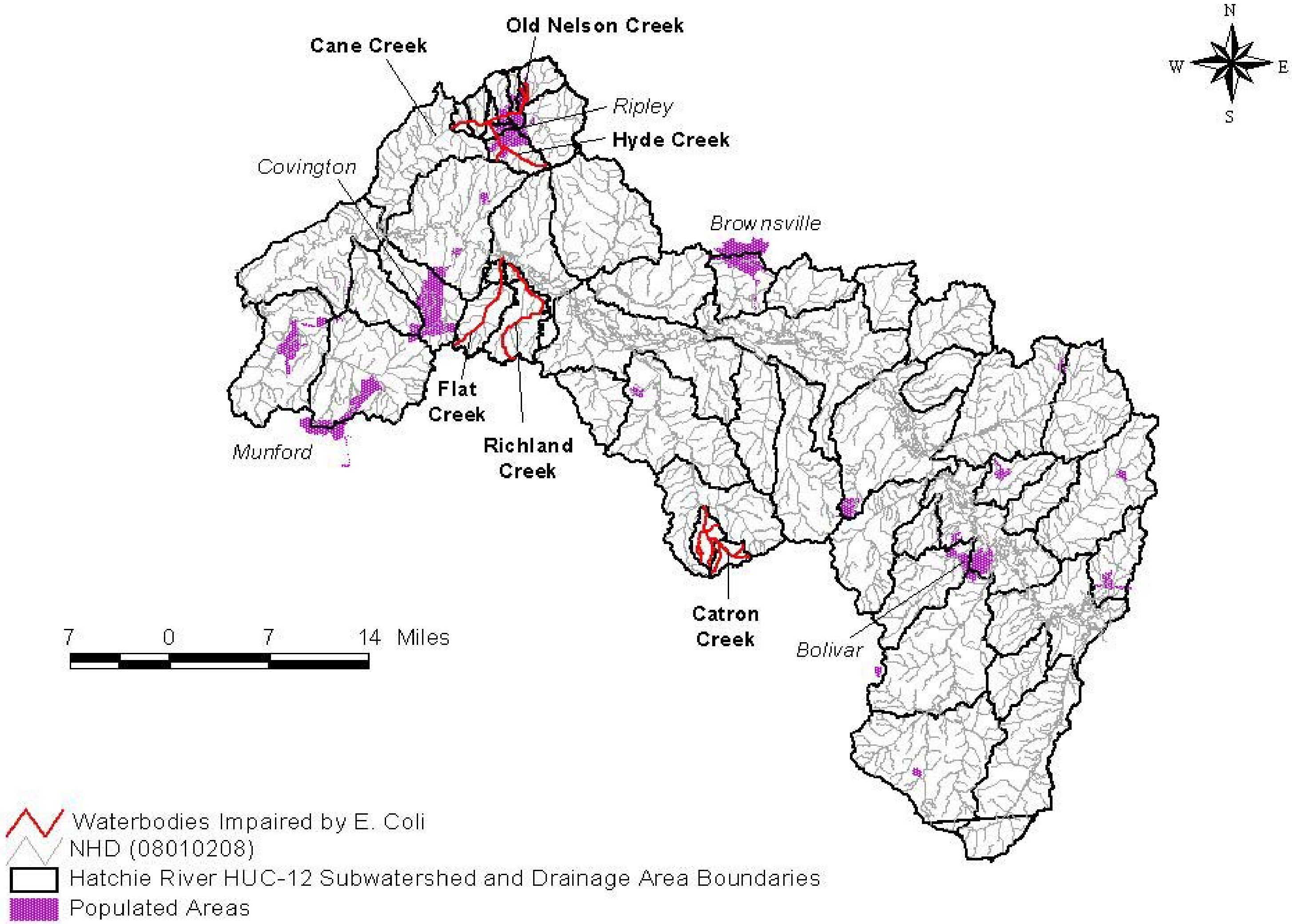

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Hatchie River waterbodies include fish & aquatic life, irrigation, livestock watering & wildlife, and recreation. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004a).

As of February 2, 2006, none of the E. coli impaired waterbodies in the Hatchie River watershed have been designated as either State Scenic River, Tier II, or Tier III streams.

For further information concerning Tennessee's general water quality criteria and Tennessee's Antidegradation Statement, including the definition of high quality waters, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

The geometric mean standard for the E. coli group of 126 CFU/100 mL and the sample maximum of 941 CFU/100 mL have been selected as the appropriate numerical targets for TMDL development for the E. coli impaired waterbodies in the Hatchie River watershed.

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are multiple water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Hatchie River watershed:

- HUC-12 080102080501:
  - CATRO003.1FA – Catron Creek, at Old Brownsville Road
- HUC-12 080102080601:
  - FLAT001.8TI – Flat Creek, at Antioch Road
  - RICHL001.8TI – Richland Creek, at Antioch Road
- HUC-12 080102080701:
  - CANE015.5LE – Cane Creek, at Cleveland Street
  - ONELS1T0.6LE – Old Channel Nelson Creek – Unnamed Tributary, at Hwy 209
  - HYDE001.6LE – Hyde Creek, at Kellar Avenue
- HUC-12 080102080702:
  - CANE012.5LE – Cane Creek, at Grimes Store Road

The locations of these monitoring stations are shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 941 CFU /100 mL maximum E. coli standard at all monitoring stations where E. coli samples were collected. Water quality monitoring results are summarized in Table 3.

Each water quality monitoring station (Table 3 and Appendix B) has at least one E. coli sample value reported as >2419.2. In addition, at five of the seven sites, the maximum E. coli sample value is >2419.2. For the purpose of calculating summary data statistics, TMDLs, Waste Load Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2419.2. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol. See Section 9.4.

There were not enough data to calculate the geometric mean at any of the monitoring stations. Whenever a minimum of 5 samples is collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean is calculated.

Table 3. Summary of Water Quality Monitoring Data

Monitoring Station	E. Coli (Single Sample Max. WQ Target = 941 CFU/100 mL)					
	Data Pts.	Date Range	[CFU/100 mL]			Exceed WQ Max. Target
			Min.	Avg.	Max.	
CATRO003.1FA	9	7/04-6/05	80.5	1761	8164	4
FLAT001.8TI	16	12/99-6/05	10.8	408	>2419.2	2
RICHL001.8TI	19	12/99-6/05	7.2	535	>2419.2	4
CANE015.5LE	12	5/00-4/01	73.8	801	>2419.2	4
ONELS1T0.6LE	13	4/00-4/01	1	481	>2419.2	3
HYDE001.6LE	10	6/00-4/01	158	2842	9804	5
CANE012.5LE	12	5/00-4/01	25.9	610	>2419.2	3

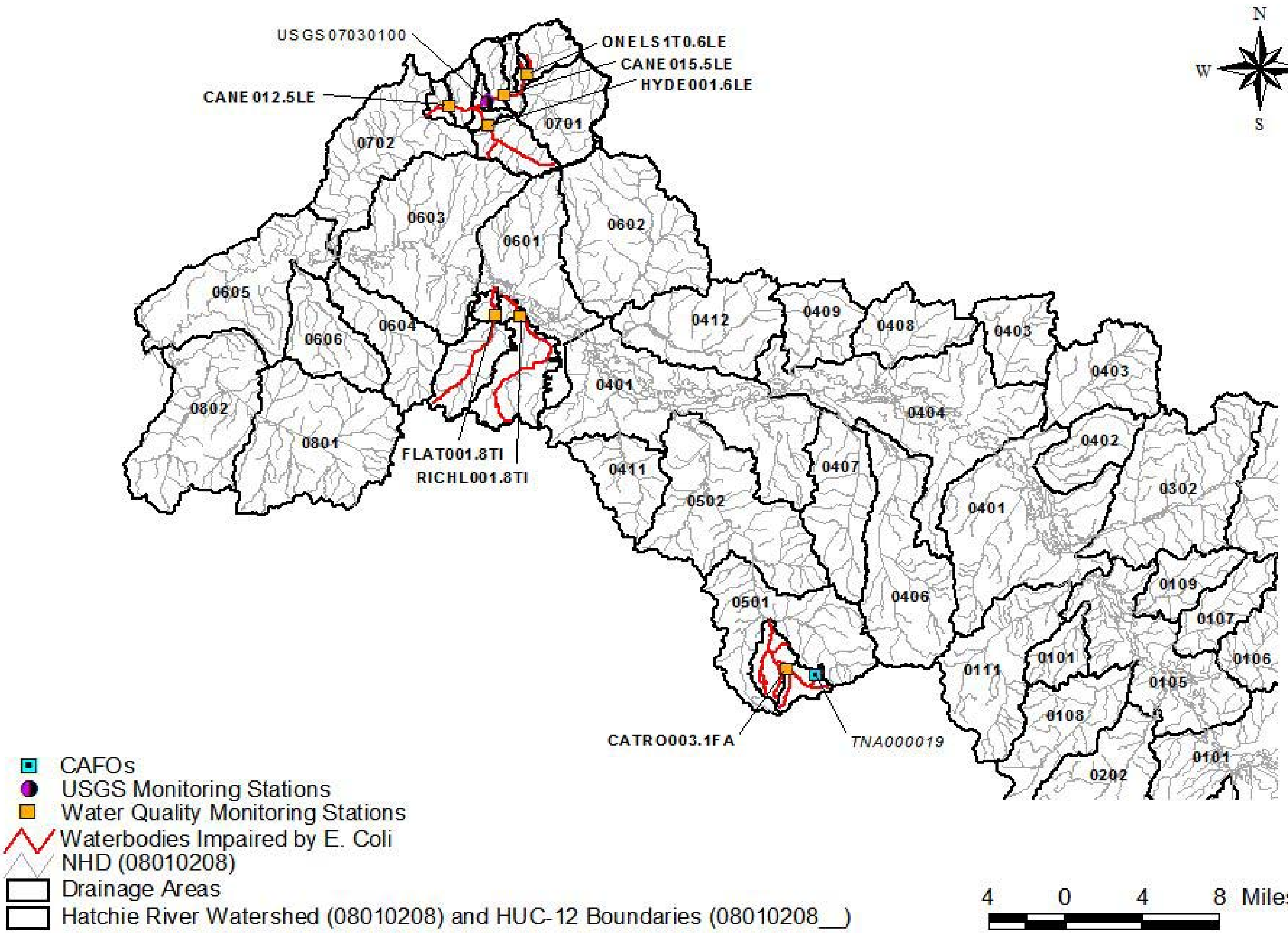

Figure 5. Monitoring Stations and CAFOs located in the Hatchie River Watershed.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect E. coli loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2 (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm), a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program (http://cfpub1.epa.gov/npdes/index.cfm) regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal (http://cfpub1.epa.gov/npdes/home.cfm?program_id=13) and industrial (http://cfpub1.epa.gov/npdes/home.cfm?program_id=14) wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6); and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs) (http://cfpub1.epa.gov/npdes/home.cfm?program_id=7). A TMDL must provide WLAs for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a LA for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There was one (1) NPDES permitted WWTF in the impaired subwatersheds of the Hatchie River watershed authorized to discharge treated sanitary wastewater during the TMDL analysis period. This facility, the Ripley Sewage Treatment Plant (STP), NPDES permit number TN0025364, that discharged to Cane Creek at mile 15.4, was discontinued in October, 2006. The facility was subsequently replaced by the new City of Ripley wastewater treatment lagoon, NPDES permit number TN0078191. The new facility discharges to the Mississippi River, outside the Hatchie River watershed. The permit limits for discharges from this WWTF are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for protection of the recreation use classification.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems (LCSs) and sanitary sewer overflows (SSOs).

Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase1) requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, there are no MS4s of this size in the Hatchie River watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase2). A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf), (TDEC, 2003). There are no permitted Phase II MS4s located in the drainage areas of (E. coli) 303(d)-listed waterbodies in the Hatchie River Watershed.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State road and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas. TDOT's individual MS4 permit may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website: http://state.tn.us/environment/wpc/stormh2o/TNS077585.pdf.

For information regarding storm water permitting in Tennessee, see the TDEC website: http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of E. coli loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* (http://state.tn.us/environment/wpc/programs/cafo/CAFO_GP_04.pdf), while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of November 2007, there was one Class II CAFO in the Hatchie River watershed with coverage under the general NPDES permit. This CAFO (TNA000019) is located in the drainage area of the (E. coli) 303(d)-listed waterbody Catron Creek, TN08010208007-0200. There were no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture (http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm). Livestock data, for counties containing E. coli-impaired subwatersheds, are summarized in Table 5. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.3 Failing Septic Systems

Some coliform loading in the Hatchie River watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 2000 county census data of people in E. coli-impaired subwatersheds of the Hatchie River watershed utilizing septic systems were compiled using the WCS and are summarized in Table 5. In western Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 4. Livestock Distribution in the Hatchie River Watershed

County Name	Livestock Population (2002 Census of Agriculture)*						
	Beef Cow	Milk Cow	Hogs	Sheep	Poultry (Layers)	Poultry (Broilers)	Horses
Fayette	10,754	732	11,378	132	541	64	2,226
Haywood	3,016	0	222	10	149	(D)	600
Lauderdale	(D)	(D)	492	46	136	112	681
Tipton	5,763	0	46	250	1,135	(D)	823

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. The Hatchie River HUC-12 subwatershed 080102080701 (Ripley area) has the highest percentage of urban land area for impaired subwatersheds in the Hatchie River watershed, with 8.1%. Land use for the Hatchie River impaired HUC-12 subwatersheds and drainage areas is summarized in Figures 6-9 and tabulated in Appendix A.

Table 5. Population on Septic Systems in the Hatchie River Watershed

HUC-12 Subwatershed (08010208__) or Drainage Area	Population on Septic Systems
Catron Creek DA	379
Flat Creek DA	874
Richland Creek DA	1040
0701 (Cane Creek)	1373
Cane Creek (034-2000) DA	1594

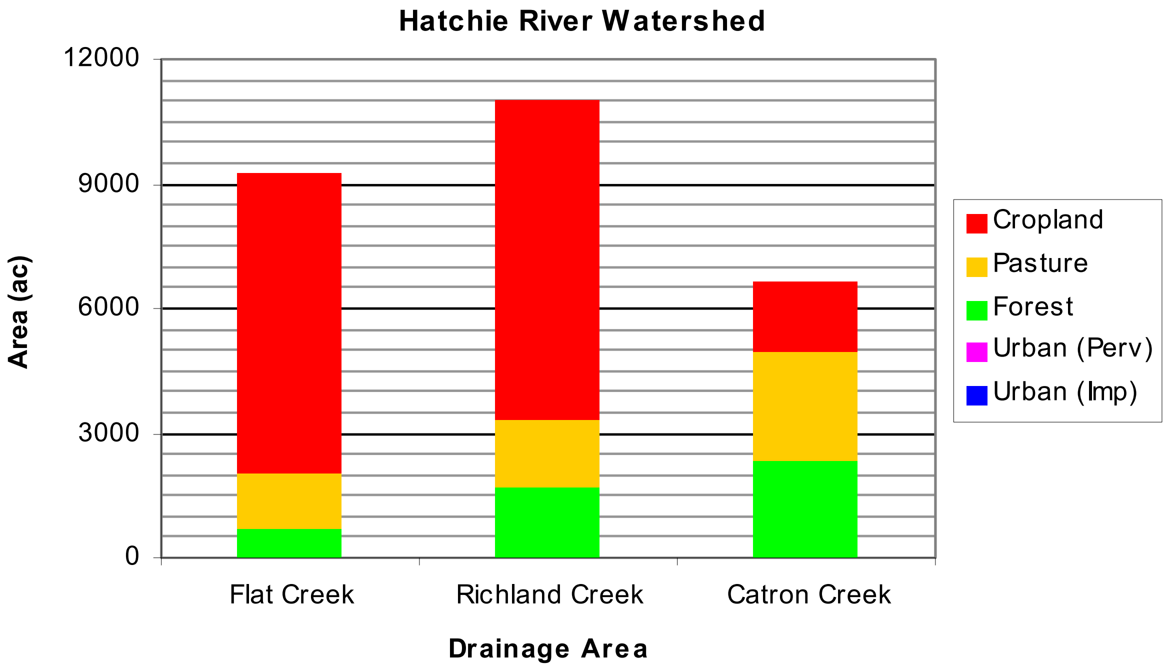

Figure 6. **Land Use Area of Hatchie River Watershed Drainage Areas Flat Creek, Richland Creek, and Catron Creek.**

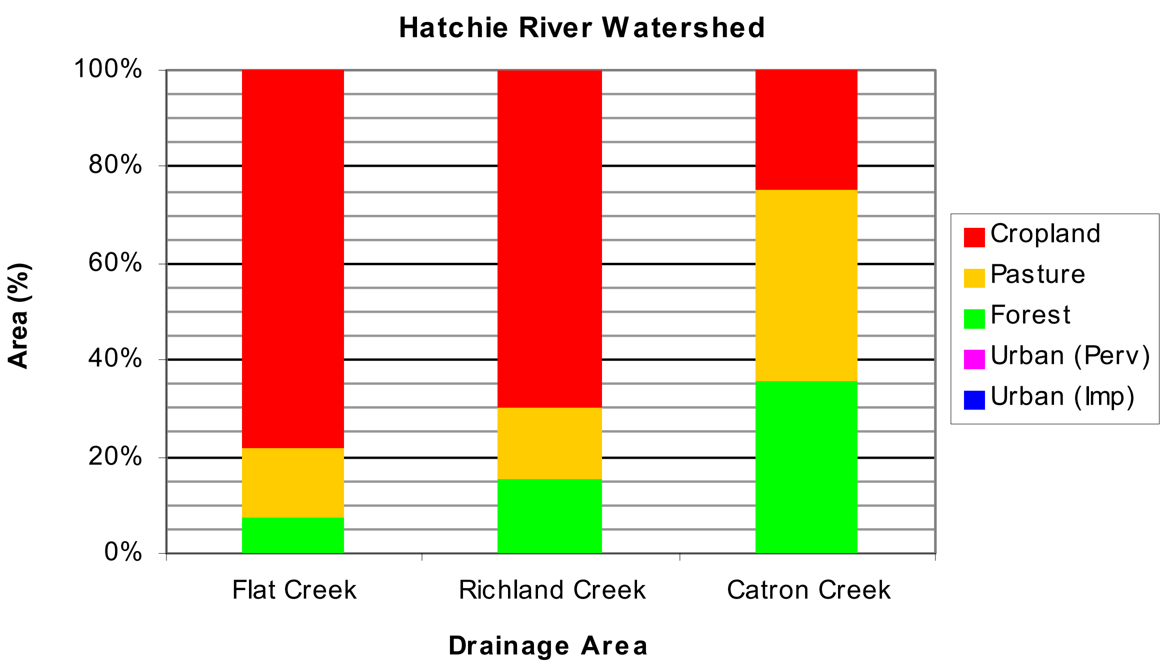

Figure 7. **Land Use Percent of Hatchie River Watershed Drainage Areas Flat Creek, Richland Creek, and Catron Creek.**

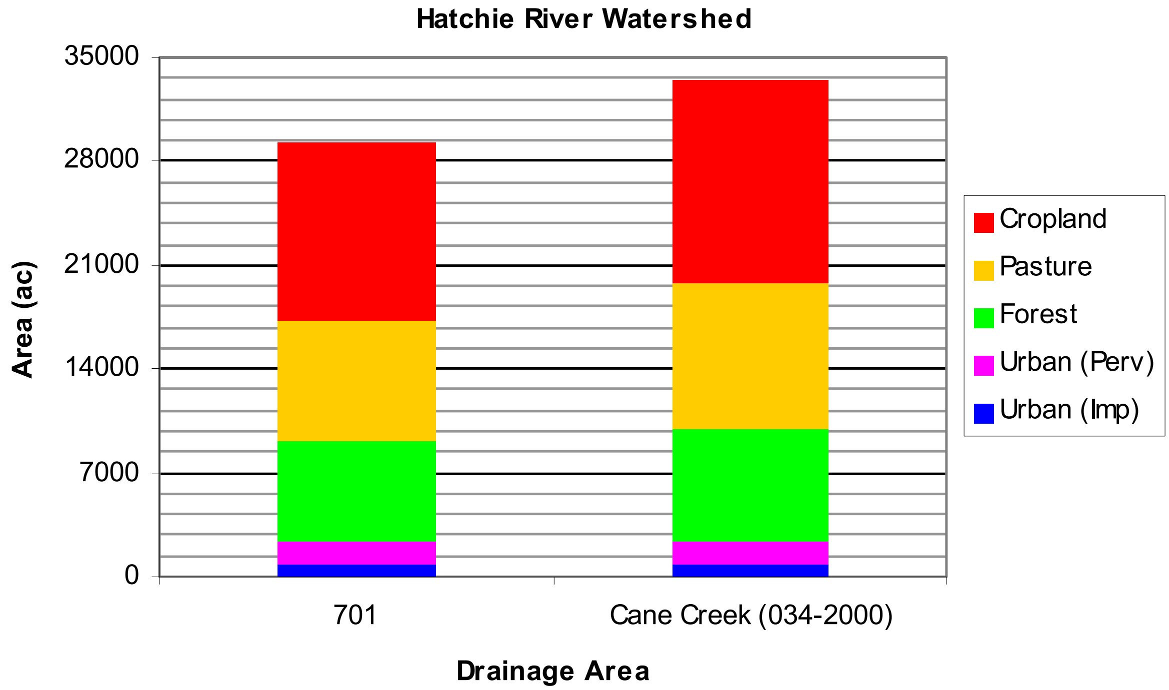

Figure 8. **Land Use Area of Hatchie River HUC-12 Subwatershed 0701 and Drainage Area Cane Creek Waterbody TN08010208034-2000.**

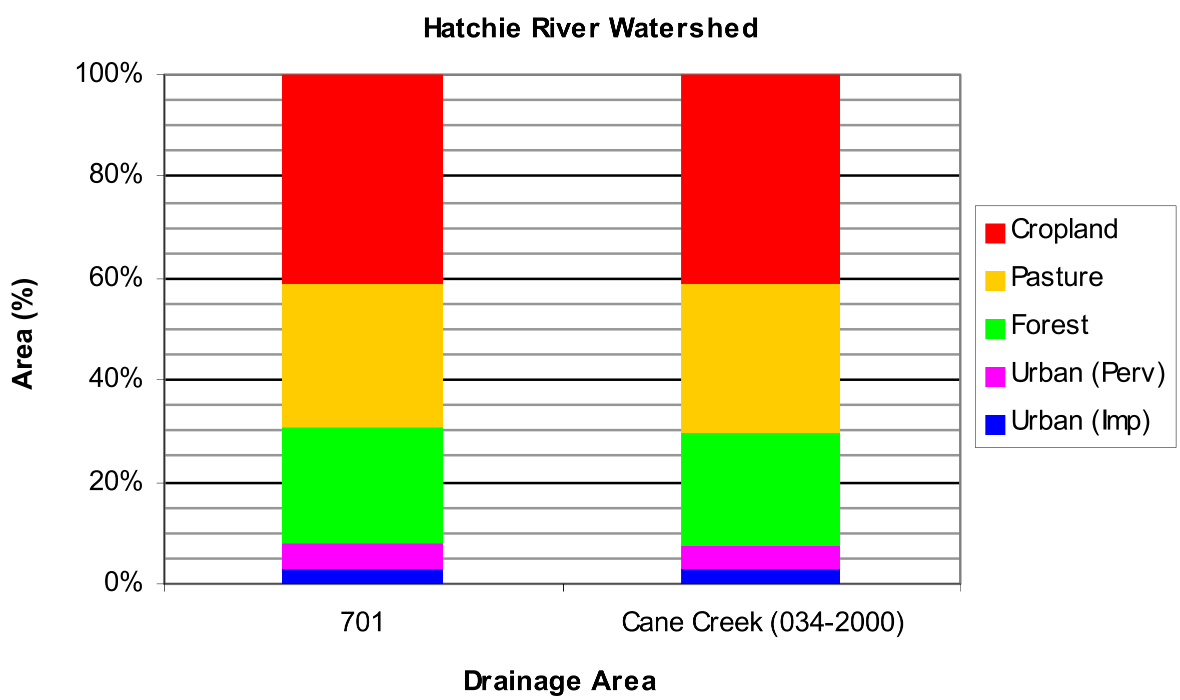

Figure 9. **Land Use Percent of Hatchie River HUC-12 Subwatershed 0701 and Drainage Area Cane Creek Waterbody TN08010208034-2000.**

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) development for waterbodies identified as impaired due to E. coli on the Final 2006 303(d) List.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is a daily load expressed as a function of mean daily flow (daily loading function). For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease E. coli loads to TMDL target levels, within each respective flow zone, are also expressed. WLAs & LAs for precipitation-induced loading sources are also expressed as daily loading functions in CFU/day/acre. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for “other direct sources”) are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2006 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 6) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

8.3 TMDL Analysis Methodology

TMDLs for the Hatchie River Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS. In addition, load reductions (PLRGs) for each flow zone were calculated for prioritization of implementation measures according to the methods described in Appendix E.

Table 6. Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (08010208)	Impaired Waterbody	Area
0501	Catron Creek	DA*
0601	Flat Creek	DA*
	Richland Creek	DA*
0701	Old Channel of Nelson Creek Hyde Creek Cane Creek	HUC-12
0702	Cane Creek	DA

* Drainage Area

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analyses.

The ten-year period from January 1, 1996 to December 31, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In most subwatersheds, water quality data have been collected during most flow ranges. For each subwatershed, the critical flow zone has been identified based on the incremental levels of impairment relative to the target loads. Based on the location of the water quality exceedances on the load duration curves, no one delivery mode for E. coli appears to be dominant (see Sections 9.1.2 and 9.1.3 and Appendix E).

Seasonal variation was incorporated in the load duration curves by using the entire 10-year simulation period and all water quality data collected at the monitoring stations. Water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of E. coli TMDLs in the Hatchie River Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum: MOS = 94 CFU/100 ml

30-Day Geometric Mean: MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli load reductions were calculated for impaired segments in the Hatchie River watershed using LDCs to evaluate compliance with the single sample maximum target concentrations according to the procedure in Appendix C. These TMDL load reductions for impaired segments and subsequent subwatersheds are shown in Table 7.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the available loading after application of the explicit MOS. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge (with few exceptions in Tennessee) and recognition that loading from these facilities is generally small in comparison to other loading sources, further reductions are not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs & LAs are summarized in Table 7.

Table 7. WLAs & LAs for Hatchie River, Tennessee

HUC-12 Subwatershed (08010208__)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs				LAs
					WWTFs[a] Daily Max.	Leaking Collection Systems	CAFOs	MS4s[b]	
			[CFU/day]	[CFU/day]	[CFU /day]	[CFU /day]	[CFU /day]	[CFU/day/ac]	[CFU/day/ac]
0501	Catron Creek	TN08010208007 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	0	NA	$3.12 \times 10^{6} * Q$
0601	Flat Creek	TN08010208056 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	NA	$2.23 \times 10^{6} * Q$
	Richland Creek	TN08010208073 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	NA	NA	NA	$1.88 \times 10^{6} * Q$
0701	Old Channel of Nelson Creek	TN08010208034 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$9.18 \times 10^{7} * Q$
	Hyde Creek	TN08010208034 – 0300	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$3.10 \times 10^{6} * Q$
	Cane Creek	TN08010208034 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$7.19 \times 10^{5} * Q$
	Cane Creek	TN08010208034 – 3000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$1.12 \times 10^{6} * Q$
0702	Cane Creek	TN08010208034 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	NA	NA	$6.27 \times 10^{5} * Q$

Note: *NA = Not applicable.*
Q = Mean Daily In-stream Flow (cfs).

a. *There are currently no WWTFs permitted to discharge E. coli in impaired subwatersheds of the Hatchie River watershed. WLAs for WWTFs expressed as E. coli loads (CFU/day). Future WWTFs must meet water quality standards as specified in their NPDES permits.*

b. *There are currently no MS4s in impaired subwatersheds of the Hatchie River watershed. Future MS4s will be assigned waste load allocations (WLAs) consistent with load allocations (LAs) assigned to precipitation induced nonpoint sources.*

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Hatchie River watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

9.1 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve (LDC) methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting management strategies for appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point source problems. The load duration curve analysis can be utilized for implementation planning. See Cleland (2003) for further information on duration curves and TMDL development, and: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf

9.1.1 Flow Zone Analysis for Implementation Planning

A major advantage of the duration curve framework in TMDL development is the ability to provide meaningful connections between allocations and implementation efforts (USEPA, 2006). Because the flow duration interval serves as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree), allocations and reduction goals can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allows the development of allocation tables (USEPA, 2006) (Appendix E), which can be used to guide potential implementation actions to most effectively address water quality concerns.

For the purposes of implementation strategy development, available E. coli data are grouped according to flow zones, with the number of flow zones determined by the HUC-12 subwatershed or drainage area size, the total contributing area (for non-headwater HUC-12s), and/or the baseflow characteristics of the waterbody. In general, for drainage areas greater than 40 square miles, the duration curves will be divided into five zones (Figure 10): high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). For smaller drainage areas, flows occurring in the low flow zone (baseflow conditions) are often extremely low and difficult to measure accurately. In many small drainage areas, extreme dry conditions are characterized by zero flow for a significant percentage of time. For this reason, the low flow zone is best characterized as a broader range of conditions (or percent time) with subsequently fewer flow zones. Therefore, for most HUC-12 subwatershed drainage areas less than 40 square miles, the duration curves will be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Some small (<40 mi^2) waterbody drainage areas have sustained baseflow (no

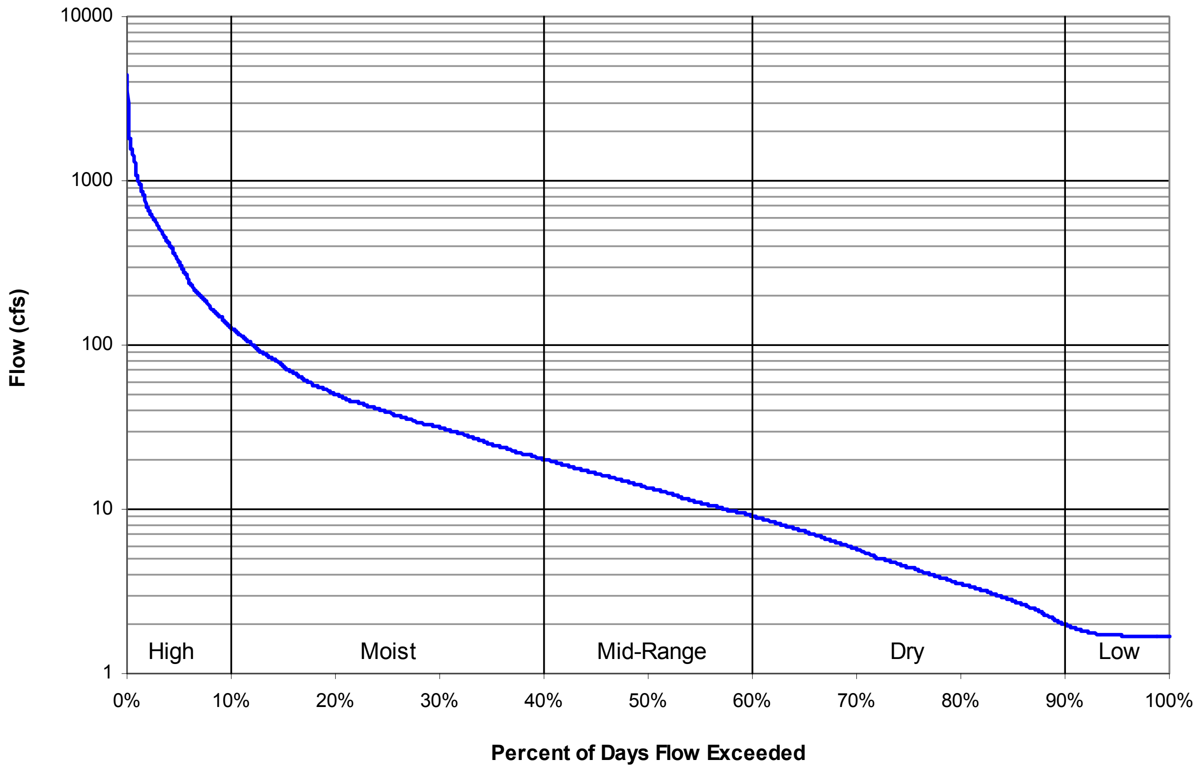

Figure 10. Five-Zone Flow Duration Curve for Cane Creek at RM 12.5.

zero flows) throughout their period of record. For these waterbodies, the duration curves will be divided into five zones.

Given adequate data, results (allocations and percent load reduction goals) will be calculated for all flow zones; however, less emphasis is placed on the upper 10% flow range for pathogen (E. coli) TMDLs and implementation plans. The highest 10 percent flows, representing flood conditions, are considered non-recreational conditions: unsafe for wading and swimming. Humans are not expected to enter the water due to the inherent hazard from high depths and velocities during these flow conditions. As a rule of thumb, the *USGS Field Manual for the Collection of Water Quality Data* (Lane, 1997) advises its personnel not to attempt to wade a stream for which values of depth (ft) multiplied by velocity (ft/s) equal or exceed 10 ft^2/s to collect a water sample. Few observations are typically available to estimate loads under these adverse conditions due to the difficulty and danger of sample collection. Therefore, in general, the 0-10% flow range is beyond the scope of pathogen TMDLs and subsequent implementation strategies.

9.1.2 Existing Loads and Percent Load Reductions

Each impaired waterbody has a characteristic set of pollutant sources and existing loading conditions that vary according to flow conditions. In addition, maximum allowable loading (assimilative capacity) of a waterbody varies with flow. Therefore, existing loading, allowable loading, and percent load reduction expressed at a single location on the LDC (for a single flow condition) do not appropriately represent the TMDL in order to address all sources under all flow conditions (i.e., at all times) to satisfy implementation objectives. The LDC approach provides a methodology for determination of assimilative capacity and existing loading conditions of a waterbody for each flow zone. Subsequently, each flow zone, and the sources contributing to impairment under the corresponding flow conditions, can be evaluated independently. Lastly, the critical flow zone (with the highest percent load reduction goal) can be identified for prioritization of implementation actions.

Existing loading is calculated for each individual water quality sample as the product of the sample flow (cfs) times the single sample E. coli concentration (times a conversion factor). A percent load reduction is calculated for each water quality sample as that required to reduce the existing loading to the product of the sample flow (cfs) times the single sample maximum water quality standard (times a conversion factor). For samples with negative percent load reductions (non-exceedance: concentration below the single sample maximum water quality criterion), the percent reduction is assumed to be zero. The percent load reduction goal (PLRG) for a given flow zone is calculated as the mean of all the percent load reductions for a given flow zone. See Appendix E.

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG, excluding the “high flow” zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG in this zone is greater than all the other zones, the zone with the second highest PLRG will be considerd the critical flow zone. The critical conditions are such that if water quality standards were met under those conditions, they would likely be met overall.

9.2 Point Sources

9.2.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. With few exceptions, in Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.2.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Plan (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at:

http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see: http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.

- Analytical monitoring of pollutants of concern (e.g., monthly) in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time. In addition, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.2.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to most CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Provisions of the general permit include development and implementation of Nutrient Management Plan (NMPs), requirements regarding land application BMPs, and requirements for CAFO liquid waste management systems. For further information, see: http://state.tn.us/environment/wpc/permits/cafo.shtml.

Provisions of individual CAFO permits are similar.

9.3 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. The Nature Conservancy initiated a community-based conservation effort within the Hatchie River

Watershed in 1999. The vision of the project is to work with public and private partners to provide sustainable natural resource practices and management within the Hatchie watershed which will promote economic, cultural, and natural diversity. For more information, please visit: http://www.nature.org/wherewework/northamerica/states/tennessee/preserves/art10171.html.

The Chickasaw-Shiloh Resource Conservation and Development (RC&D) Council was authorized by the U.S. Department of Agriculture for operation in April of 1976. The area is located in west Tennessee and includes Chester, Fayette, Hardeman, Haywood, and Madison Counties. The Council has assisted the citizens of the area develop and implement a wide array of projects. Priority concerns addressed by the Council include water quality issues, inadequate community infrastructure, and urbanization.

The Friends of West TN Refuges is a non-profit organization designed to help the refuges of Tennessee through fundraising and volunteer work. Their mission is to promote and enhance the integrity of the West Tennessee National Wildlife Refuges through activities that advance public understanding, awareness, appreciation, and enjoyment of the natural environment. Their goals are to support refuge activities and events, increase awareness of West Tennessee Refuges, educate the public about The U.S. Fish & Wildlife Service's mission, and to increase fundraising to support refuge programs. They have achieved funding for our Backyard Habitat, Junior Ranger Program, water delivery systems, and 3 observation towers.

9.3.1 Urban Nonpoint Sources

Management measures to reduce pathogen loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 9.2.2). Specific categories of urban nonpoint sources include stormwater, illicit discharges, septic systems, pet waste, and wildlife:

Stormwater: Most mitigation measures for stormwater are not designed specifically to reduce bacteria concentrations (ENSR, 2005). Instead, BMPs are typically designed to remove sediment and other pollutants. Bacteria in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in bacteria concentrations.

Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Septic systems: When properly installed, operated, and maintained, septic systems effectively reduce pathogen concentrations in sewage. To reduce the release of pathogens, practices can be employed to maximize the life of existing systems, identify failed systems, and replace or remove failed systems (USEPA, 2005a). Alternatively, the installation of public sewers may be appropriate.

Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA, 2002b).

Wildlife: Reducing the impact of wildlife on pathogen concentrations in waterbodies generally requires either reducing the concentration of wildlife in an area or reducing their proximity to the waterbody (ENSR, 2005). The primary means for doing this is to eliminate human inducements for congregation. In addition, in some instances population control measures may be appropriate.

Two additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://www.epa.gov/owow/nps/urbanmm/index.html) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap1.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban stormwater management (Publication Number EPA/600/R-04/184, September 2004).

9.3.2 Agricultural Nonpoint Sources

BMPs have been utilized in the Hatchie River watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., pasture and hayland planting, cropland conversion, riprap and cattle panel drop chute, diversion, pond, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Hatchie River E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Hatchie River watershed are shown in Figure 11. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future TMDL analysis efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained and their performance (in source reduction) evaluated over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

For additional information on agricultural BMPs in Tennessee, see: http://state.tn.us/agriculture/nps/bmpa.html

An additional agricultural nonpoint source resource provided by EPA is *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (http://www.epa.gov/owow/nps/agmm/index.html): a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and ground water from agriculture (EPA 841-B-03-004, July 2003).

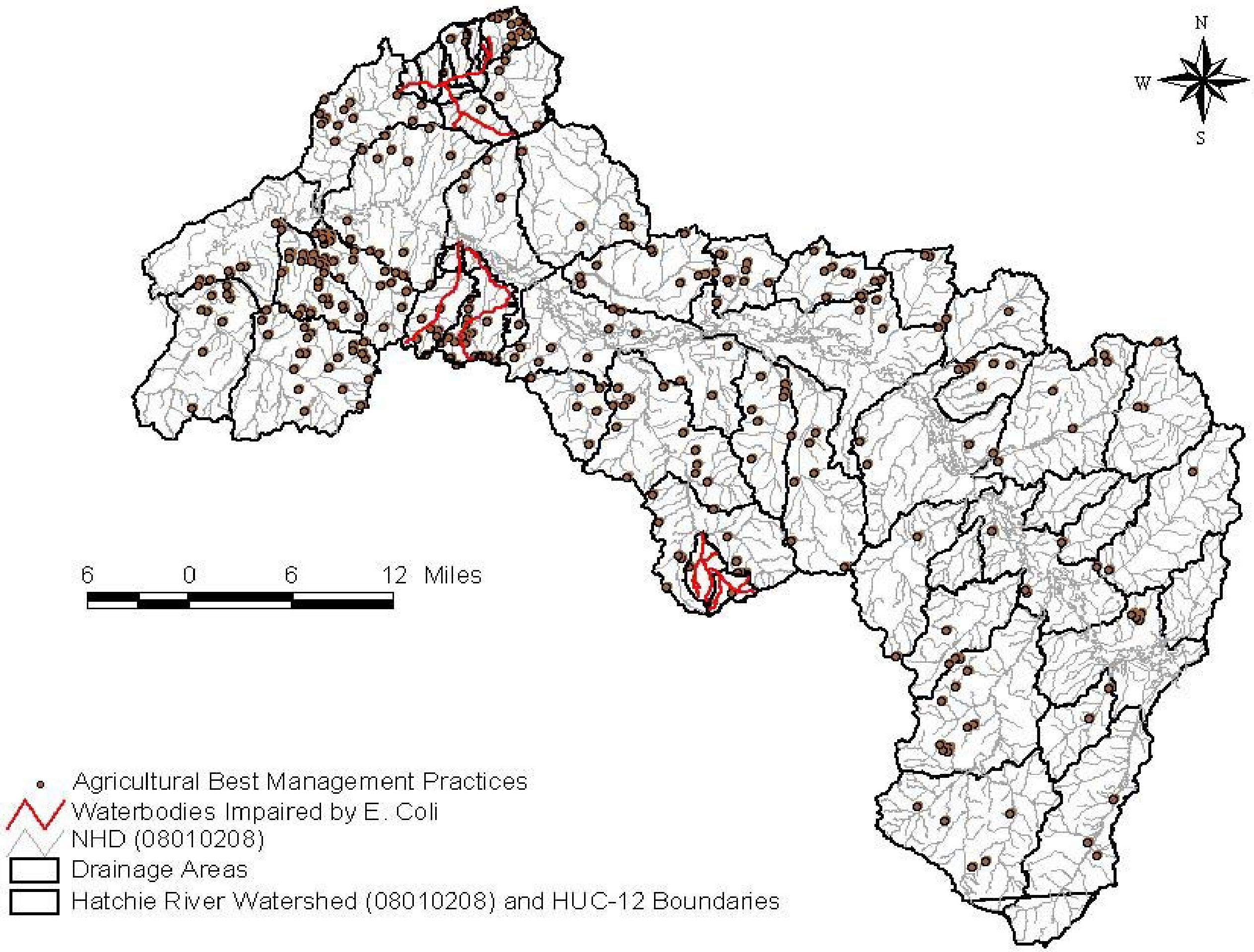

Figure 11. Tennessee Department of Agriculture Best Management Practices in the Hatchie River Watershed.

9.3.3 Other Nonpoint Sources

Additional nonpoint source references (not specifically addressing urban and/or agricultural sources) provided by EPA include:

National Management Measures to Control Nonpoint Source Pollution from Forestry (http://www.epa.gov/owow/nps/forestrymgmt/) helps forest owners protect lakes and streams from polluted runoff that can result from forestry activities. These scientifically sound techniques are the best practices known today. The report will also help states to implement their nonpoint source control programs (EPA 841-B-05-001, May 2005).

In addition, the EPA website, http://www.epa.gov/owow/nps/bestnpsdocs.html, contains a list of guidance documents endorsed by the Nonpoint Source Control Branch at EPA headquarters. The list includes documents addressing urban, agriculture, forestry, marinas, stream restoration, nonpoint source monitoring, and funding.

9.4 Additional Monitoring

Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of in-stream water quality targets for E. coli.

9.4.1 Water Quality Monitoring

Activities recommended for the Hatchie River watershed:

Verify the assessment status of stream reaches identified on the Final 2006 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of TMDLs should be acquired. TMDLs will be revisited on 5-year watershed cycle as described above.

Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by permitees and stakeholders. Where required TMDL loading reduction has been fully achieved, adequate data to support delisting should be collected.

Provide additional data to clarify status of ambiguous sites (e.g., geometric mean data) for potential listing. Analyses of existing data at several monitoring sites on unlisted waterbodies in the Hatchie River watershed suggest levels of impairment. Therefore, additional data are required for listing determination.

Continue ambient (long-term) monitoring at appropriate sites and key locations.

Comprehensive water quality monitoring activities include sampling during all seasons and a broad range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2004b).

9.4.2 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as "genetic fingerprinting"), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) has developed and tested a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources.

A good example of this in west Tennessee: the City of Memphis conducted a Microbial Source Tracking Study for South Cypress Creek, in the Nonconnah Creek watershed (Lawrence, 2003), to identify fecal sources in an urban watershed. The Institute for Environmental Health (IEH), in Seattle, WA, assisted with the project and conducted ribotyping on E. coli strains from fecal coliform samples. In addition, a library of known sources was supplemented with local data by the collection of scat samples for better matching of bacteria sources. The results indicated that human sources (including raw sewage) accounted for less than 20% of the total occurrences of E. coli from fecal samples. Avian and wild animal sources were the primary sources of fecal contributions to South Cypress Creek. The report can be found at the following websites: http://www.cityofmemphis.org/pdf_forms/MicrobialSourceTrackingStudy.pdf and http://www.cityofmemphis.org/pdf_forms/MicrobialSourceTrackingStudyFigures.pdf.

9.5 Source Area Implementation Strategy

Implementation strategies are organized according to the dominant landuse type and the sources associated with each (Table 8 and Appendix E). Each HUC-12 subwatershed or drainage area is grouped and targeted for implementation based on this source area organization. Three primary categories are identified: predominantly urban, predominantly agricultural, and mixed urban/agricultural. See Appendix A for information regarding landuse distribution of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas with predominate source categories such as point sources (WWTFs), collection systems/septic systems (including SSOs and CSOs), and urban stormwater runoff associated with MS4s. Agricultural is defined as cropland and pasture, with predominate source categories associated with livestock and manure management activities. A fourth category (infrequent) is associated with forested (including non-agricultural undeveloped and unaltered [by humans]) landuse areas with the predominate source category being wildlife.

Table 8. Source area types for waterbody drainage area analyses.

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Catron Creek		ò		
Old Channel Nelson Creek			ò	
Hyde Creek			ò	
Cane Creek (HUC-12s: 0701, 0702)			ò	
Cane Creek (HUC-12: 0701)			ò	
Flat Creek		ò		
Richland Creek		ò		

* All waterbodies potentially have significant source contributions from other source type/landuse areas.

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Table 8. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

Appendix E provides source area implementation examples for urban and agricultural subwatersheds, development of percent load reduction goals, and determination of critical flow zones (for implementation prioritization) for E. coli impaired waterbodies. Load duration curve analyses (TMDLs, WLAs, LAs, and MOS) and percent load reduction goals for all flow zones for all E. coli impaired waterbodies in the Hatchie River watershed are summarized in Table E-4.

9.5.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly urban, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 9 (USEPA, 2006). Table 9 presents example urban area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of urban management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly agricultural, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 10 (USDA, 1988). Table 10 presents example agricultural area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of agricultural management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominate source category being wildlife, in the Hatchie River watershed.

Table 9. Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L

Note: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)

Table 10. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	**H**	**H**	**M**	**L**	
Pasture & Hayland Mgmt (510)	**H**	**H**	**M**	**L**	
Deferred Grazing (352)	**H**	**H**	**M**	**L**	
Planned Grazing System (556)	**H**	**H**	**M**	**L**	
Proper Grazing Use (528)	**H**	**H**	**M**	**L**	
Proper Woodland Grazing (530)	**H**	**H**	**M**	**L**	
Livestock Access Limitation					
Livestock Exclusion (472)			**M**	**H**	**H**
Fencing (382)			**M**	**H**	**H**
Stream Crossing			**M**	**H**	**H**
Alternate Water Supply					
Pipeline (516)			**M**	**H**	**H**
Pond (378)			**M**	**H**	**H**
Trough or Tank (614)			**M**	**H**	**H**
Well (642)			**M**	**H**	**H**
Spring Development (574)			**M**	**H**	**H**
Manure Management					
Managing Barnyards	**H**	**H**	**M**	**L**	
Manure Transfer (634)	**H**	**H**	**M**	**L**	
Land Application of Manure	**H**	**H**	**M**	**L**	
Composting Facility (317)	**H**	**H**	**M**	**L**	
Vegetative Stabilization					
Pasture & Hayland Planting (512)	**H**	**H**	**M**	**L**	
Range Seeding (550)	**H**	**H**	**M**	**L**	
Channel Vegetation (322)	**H**	**H**	**M**	**L**	
Brush (& Weed) Mgmt (314)	**H**	**H**	**M**	**L**	

Table 10. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations (Cont.)

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Vegetative Stabilization (cont'd)					
Conservation Cover (327)		**H**	**H**	**H**	
Riparian Buffers (391)		**H**	**H**	**H**	
Critical Area Planting (342)		**H**	**H**	**H**	
Wetland restoration (657)		**H**	**H**	**H**	
CAFO Management					
Waste Management System (312)	**H**	**H**	**M**		
Waste Storage Structure (313)	**H**	**H**	**M**		
Waste Storage Pond (425)	**H**	**H**	**M**		
Waste Treatment Lagoon (359)	**H**	**H**	**M**		
Mulching (484)	**H**	**H**	**M**		
Waste Utilization (633)	**H**	**H**	**M**		
Water & Sediment Control Basin (638)	**H**	**H**	**M**		
Filter Strip (393)	**H**	**H**	**M**		
Sediment Basin (350)	**H**	**H**	**M**		
Grassed Waterway (412)	**H**	**H**	**M**		
Diversion (362)	**H**	**H**	**M**		
Heavy Use Area Protection (561)					
Constructed Wetland (656)					
Dikes (356)	**H**	**H**	**M**		
Lined Waterway or Outlet (468)	**H**	**H**	**M**		
Roof Runoff Mgmt (558)	**H**	**H**	**M**		
Floodwater Diversion (400)	**H**	**H**	**M**		
Terrace (600)	**H**	**H**	**M**		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

Note: Numbers in parentheses are the U.S. Soil Conservation Service practice number.

9.6 Evaluation of TMDL Implementation Effectiveness

Evaluation of the effectiveness of TMDL implementation strategies should be conducted on multiple levels, as appropriate:

- HUC-12 or waterbody drainage area (i.e., TMDL analysis location)
- Subwatersheds or intermediate sampling locations
- Specific landuse areas (urban, pasture, etc.)
- Specific facilities (WWTF, CAFO, uniquely identified portion of MS4, etc.)
- Individual BMPs

In order to conduct an implementation effectiveness analysis on measures to reduce E. coli source loading, monitoring results should be evaluated in one of several ways. Sampling results can be compared to water quality standards (e.g., load duration curve analysis) for determination of impairment status, results can be compared on a before and after basis (temporal), or results can be evaluated both upstream and downstream of source reduction measures or source input (spatial). Considerations include period of record, data collection frequency, representativeness of data, and sampling locations.

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watersheds in second or successive TMDL cycles, data collected from multiple cycles can be compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. For example, Figure 12 shows fecal coliform concentration data statistics for Oostanaula Creek at mile 28.4 (Hiwassee River watershed) for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL). The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Figure 13 shows a load duration curve analysis (of recent versus historical data) of fecal coliform loading statistics for Oostanaula Creek. Lastly, Figure 14 shows best fit curve analyses of flow (percent time exceeded) versus fecal coliform loading relationships (regressions) plotted against the LDC of the single sample maximum water quality standard. Note that Figures 12-14 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

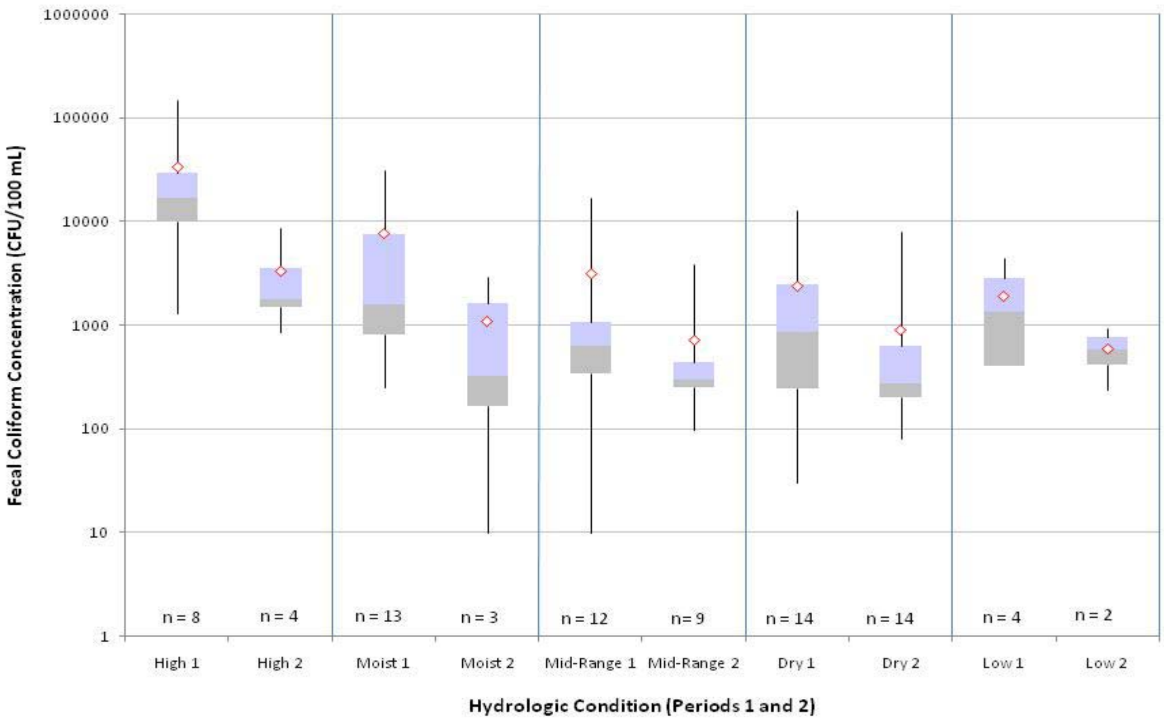

Figure 12. Oostanaula Creek TMDL implementation effectiveness (box and whisker plot).

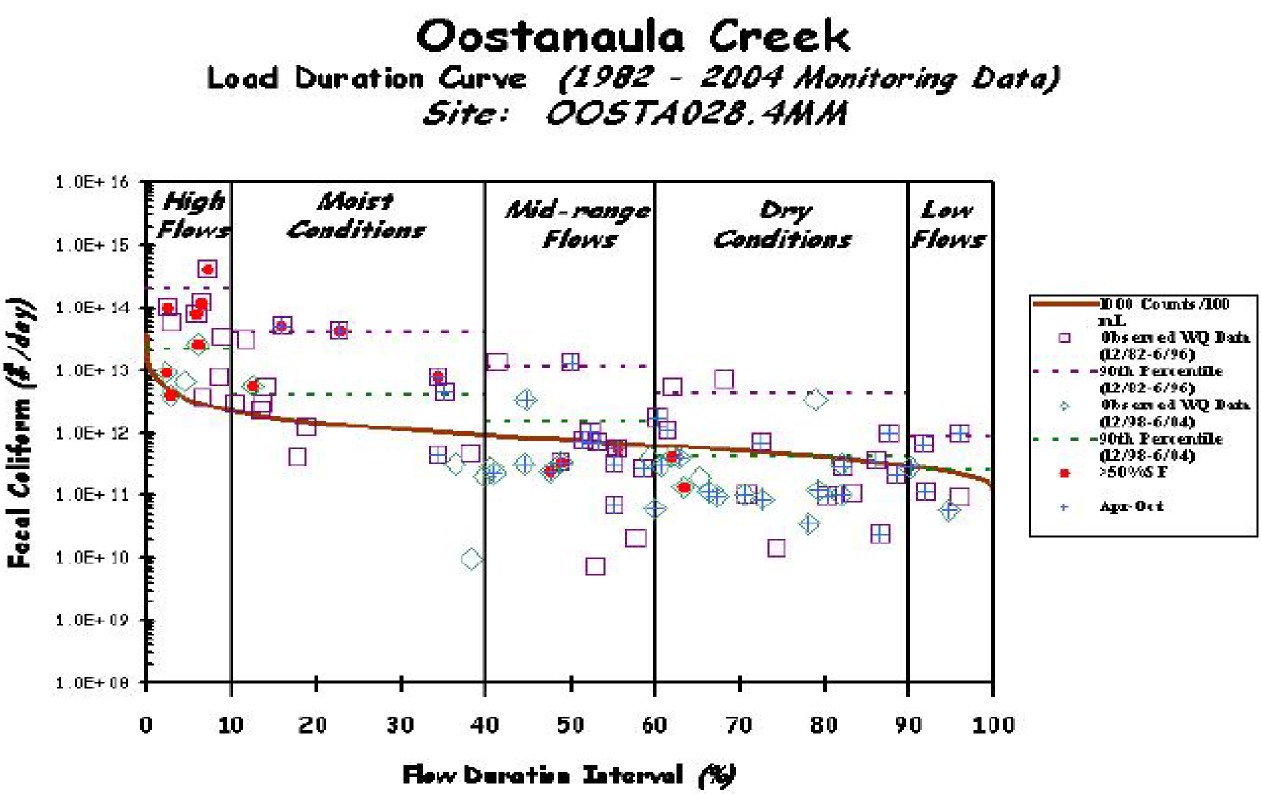

Figure 13. Oostanaula Creek TMDL implementation effectiveness (LDC analysis).

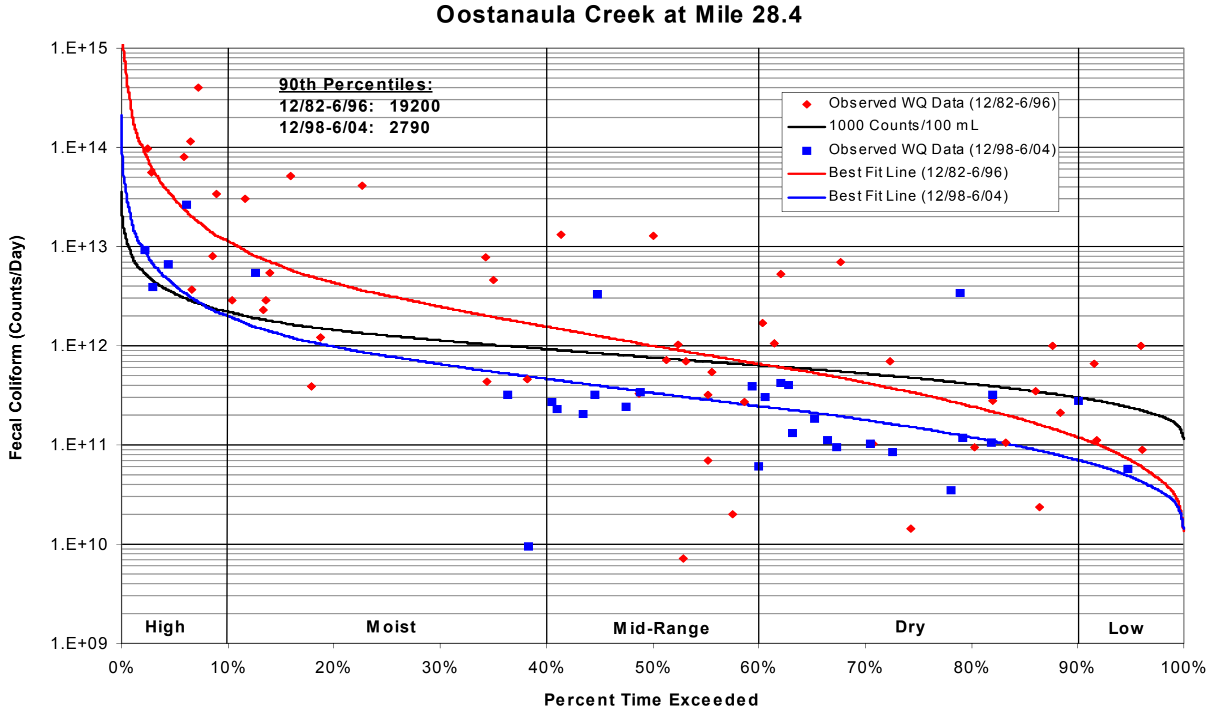

Figure 14. Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed E. coli TMDLs for the Hatchie River watershed were placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard included:

1) Notice of the proposed TMDLs was posted on the TDEC website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which were sent to approximately 90 interested persons or groups who have requested this information.

3) A draft copy of the proposed TMDLs was sent to the Tennessee Department of Transportation.

4) A letter was sent to the City of Ripley Wastewater Lagoon (TN0078191), located in an E. coli-impaired subwatershed in the Hatchie River watershed, advising them of the proposed TMDLs and their availability on the TDEC website. The letter also stated that a copy of the draft TMDL document would be provided on request.

5) Letters were sent to local stakeholder groups in the Hatchie River Watershed advising them of the proposed E. coli TMDLs and their availability on the TDEC website. The letters also stated that copies of the draft TMDL document would be provided upon request. Letters were sent to the following local stakeholder groups:

   The Nature Conservancy/The Hatchie River Project
   The Chickasaw-Shiloh Resource Conservation and Development Council
   The Friends of West TN Refuges

No written comments were received during the proposed TMDL public comment period. No requests to hold public meetings were received regarding the proposed TMDLs as of close of business on February 11, 2008.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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